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INDIANA WATER QUALITY RECREATION PROJECT GEIST RESERVOIR, INDIANAPOLIS, INDIANA

Federal Water Pollution Control Administration
Chicago, Illinois

May 1966

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INDIANA WATER QUALITY-RECREATION PROJECT

GEIST RESERVOIR

INDIANAPOLIS, INDIANA

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Federal Water Pollution Control Administration

May 1966

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PARTICIPANTS

The Geist Reservoir Study was conducted under the administrative guidance of H. W. Poston, Regional Program Director, FWPCA, Region V, and under the technical guidance of Merrill Gamet, Project Director, Indiana Water Quality-Recreation Project, Region V. Field investigations were conducted by Douglas Brackney and Clarence Monday. The assistance and recommendations of the Division of Sanitary Engineering, Indiana State Board of Health and of the Indianapolis Water Company are gratefully acknowledged. Consultative services were provided by the Technical Advisory and Investigations Activities and the Headquarters Office, Technical Services Program. The report was written by Nelson Thomas and Loys Parrish of the Technical Advisory and Investigations Activities because of project termination and reassignment of project staff.

SUMMARY

A limnological study was made of 1,800-acre Geist Reservoir, near Indianapolis, Indiana, during 1963 and 1964. The reservoir is owned by the Indianapolis Water Company and is used principally as a water storage impoundment, although limited recreational use is permitted. Fishing is the principal form of this recreational use, and 515,000 man-hours per year were spent in fishing activities on the reservoir. Objectives of the study were to evaluate possible deterioration in water quality that results from use of a watershed or reservoir for recreational purposes, and to determine the effects of water pollution sources within the drainage basin on water quality.

The study showed that temporary thermal stratification resulted in dissolved oxygen concentrations of less than 0.5 mg/l in the waters near the bottom. Along with other nutrients the lake receives annually from land runoff including waste discharges, about 793,000 pounds of inorganic nitrogen (3,700 pounds per square mile per year) and 51,000 pounds of total phosphorus (240 pounds per square mile per year). These nutrients produced a maximum standing crop (amount present) of 2,500,000 pounds (wet weight) of algae during the month of June, which was the month most productive of algae during the investigation. Concurrent with the maximum algal crop, 66,000 pounds of inorganic nitrogen and 1,900 pounds of soluble phosphorus yet remained in the reservoir and presumably was available for algal production.

A lake or reservoir retains a portion of some of the constituents that it receives which affect water quality. Geist Reservoir, in 1964, retained 44 percent of the inorganic nitrogen, 25 percent of the total phosphorus, and reduced by 90 percent the bacterial population between the inlet and outlet stations.

CONCLUSIONS

The study of Geist Reservoir, during 1963 and 1964, has shown that:

(1) the fertile drainage area was supplying sufficient nutrients and growth stimulants to Geist Reservoir for aquatic vegetation development, and that the effects of any nutrient increases resulting from currently proposed recreational use or adjacent land development would be undetectable,

(2) the nutrients and growth stimulants supplied from the drainage area are contributed by agricultural runoff, municipal-industrial discharges, and forest and non-crop land runoff. A reduction of the agricultural, municipal, and industrial wastes could improve the water quality of Geist Reservoir,*

(3) the future development of water contact sports, such as swimming, would be limited because of inadequate swimming beaches,

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* Because of possible changes in future land use or population growth that may occur in the drainage basin, a short-term limnological investigation is indicated in 1970 to identify the effects of any such changes on the reservoir water quality.

(4) the natural die-off of bacteria that occurred in Geist Reservoir indicates that under existing conditions the development of large bacterial populations within the reservoir is remote,

(5) the deterioration of water quality from chemicals introduced from outboard motor exhausts, and gasoline and oil spillages is remote because of the currently imposed restrictions as well as natural physical restrictions on this type of recreation,

(6) gross mineral analyses indicate an acceptable water quality for a public supply,

(7) analysis of data from chemical and biological determinations conducted on Geist Reservoir during 1963 and 1964 indicates that the small amount of recreation present on Geist Reservoir has a minimum effect on the present water quality.

INTRODUCTION

During recent years there has been a rapidly growing use of impounded waters for recreational purposes. In some cases, previously closed watersheds used for municipal water supply have been opened to recreational purposes and this new use has concerned public health authorities. Although the municipalities using water from these impounded sources provide conventional treatment prior to use, the effect of water contact sports, such as swimming, and other effects such as chemicals introduced from outboard motor exhausts, oil and gasoline spillages, etc. are unknown. One of the objectives of this study was to evaluate deterioration in water quality that results from extensive use of a watershed or a reservoir for recreational purposes. Other objectives included the effect of sources of water pollution within the drainage basin, on reservoir water quality and the determination of the quality of reservoir water available for a public drinking water supply.

SITE SELECTION

The selection of Geist Reservoir as a study site was based on data and other information furnished by the Indiana State Board of Health. Geist Reservoir presented a suitable study site because it was used solely as a water storage reservoir on which water skiing and swimming were prohibited. However, extensive land development

in the form of shoreline residential housing was planned that would have resulted in increased recreational expansion and usage of the reservoir. Other planned developments were the construction of a sewage treatment plant to serve the housing development and a water treatment plant. In retrospect, the shoreline housing development and the liberalized and expanded recreational usage of Geist Reservoir has not proceeded on the time schedule originally planned at the inception of the study.

PHYSICAL ASPECTS

Geist Reservoir and Drainage Basin

Geist Reservoir, Figure 1, is located approximately 15 miles northeast of Indianapolis, Indiana. The reservoir is 7.5 miles long, has a surface area of 1,800 acres, and a shoreline of 35 miles. Its storage capacity is 6.9 billion gallons.

The reservoir is divided into three unequal basins by two causeways. The upper portion is the smallest and the shallowest with a capacity of 0.2 billion gallons, and primarily represents a settling basin.

The middle portion has an average depth of 10 feet, a maximum depth of 15 feet, and a capacity of 1.1 billion gallons.

The lower basin has a capacity of 5.6 billion gallons, an average depth of 20 feet and a maximum depth of 30 feet.

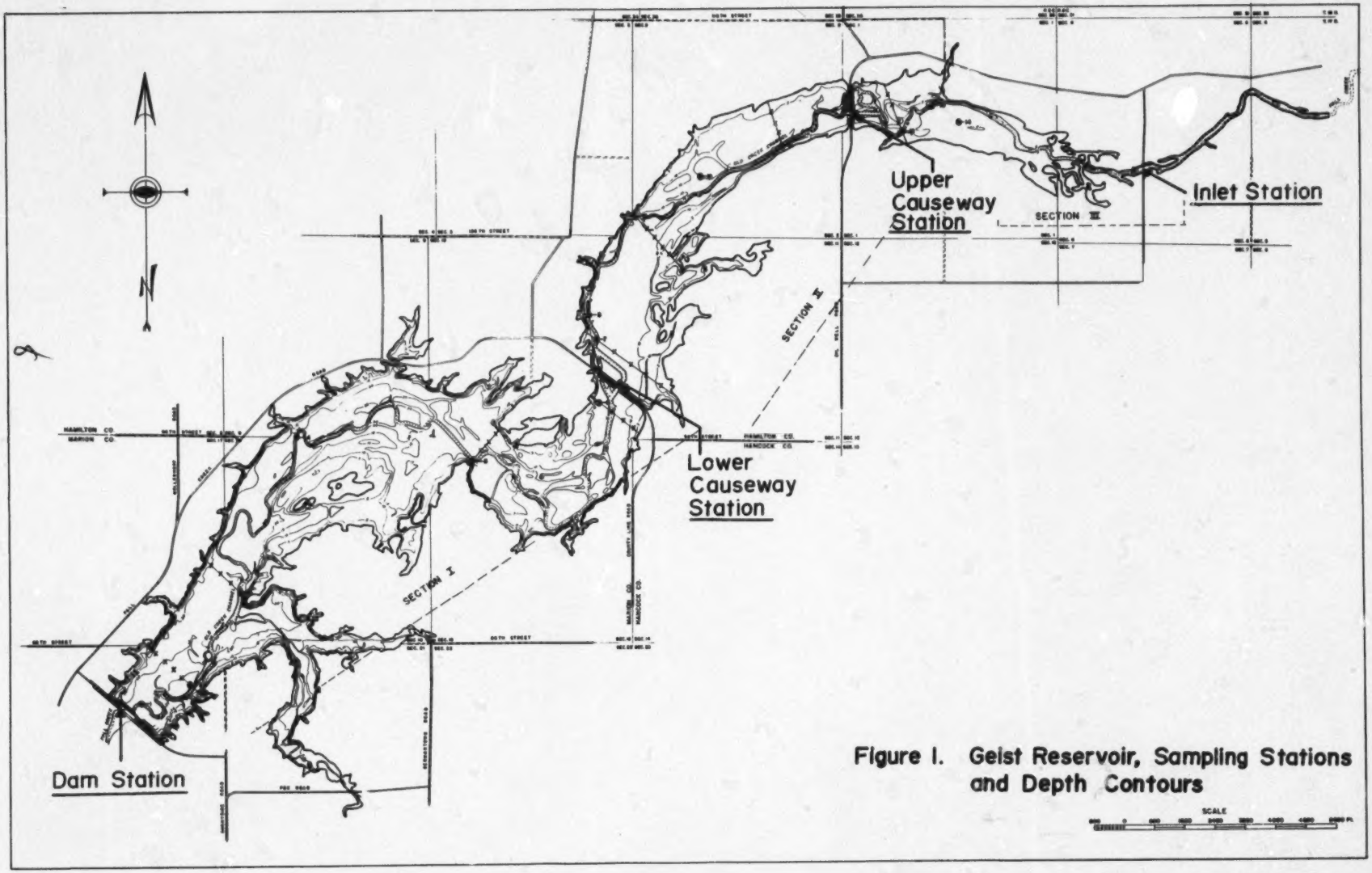

Figure I. Geist Reservoir, Sampling Stations and Depth Contours

The watershed draining into the impoundment is 215 square miles, Figure 2. The land which is primarily used for farming is gently rolling to flat Wisconsin glacial drift. There are 950 farms with a total of 137,000 acres. Principal crops are corn, wheat, soybeans and hay.

Flows

Geist Reservoir receives a flushing during March and April when it receives 90% of its influent water, Figure 3. During the low flow period, August through January, the influent is less than 25 million gallons per month. The outflow of water from Geist Reservoir is greatest during the two spring months, March and April. After the reservoir has reached its storage level the drawoff is subject to the demands of the water company. Minimum reservoir volumes of 4,500 million gallons were observed from November through February, Figure 4.

PRESENT INTENSITY OF RECREATION

Records for the calendar year 1964 from the marina located on Geist Reservoir indicate that there were 2,746 private boats that used adjacent ramp facilities and that 16,396 trips were made in rental boats. Each boat trip averaged about five hours and each boat carried an average of 2.5 people per trip. There was a total of 47,850 people fishing from boats. This is equivalent to 239,250

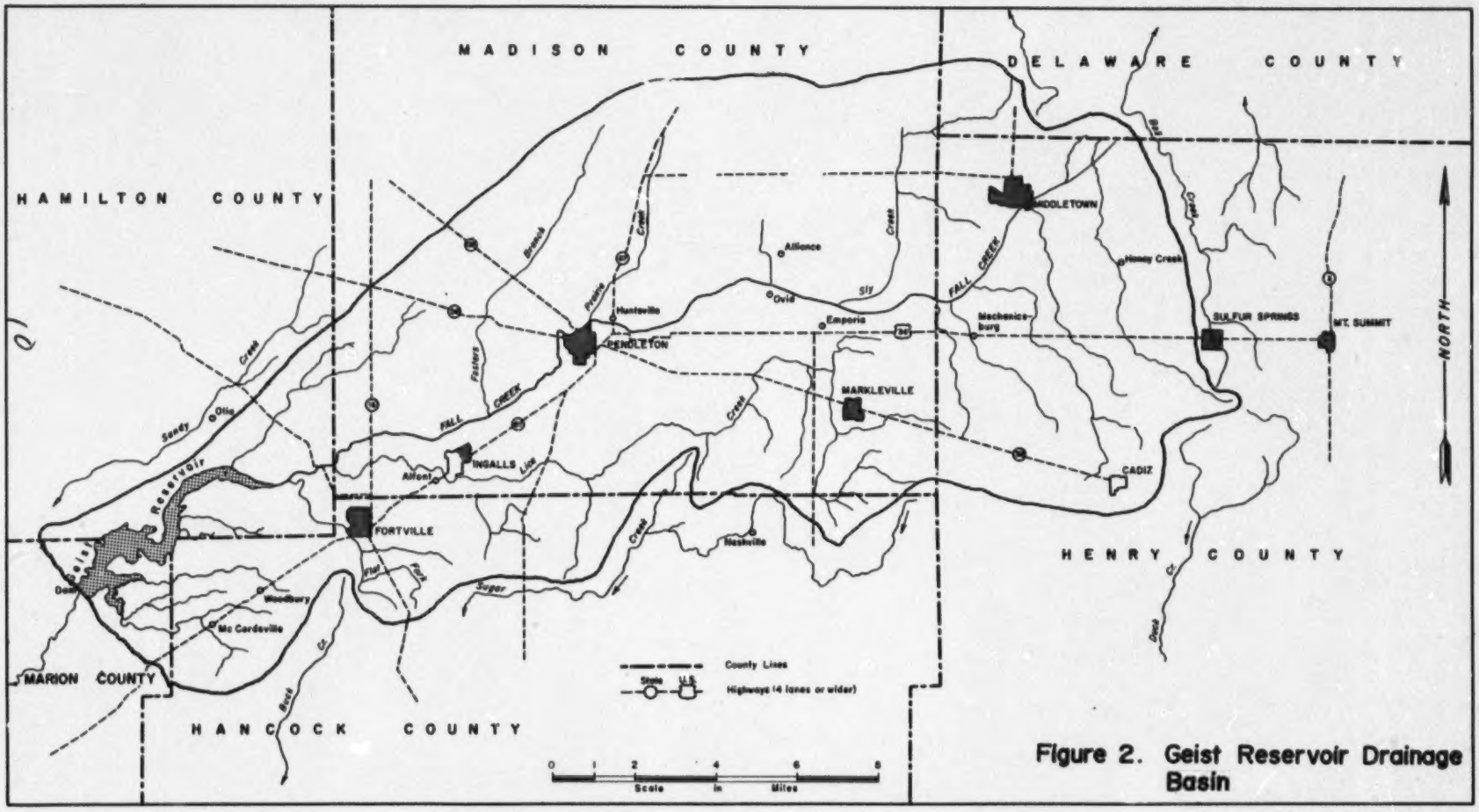

Figure 2. Geist Reservoir Drainage Basin

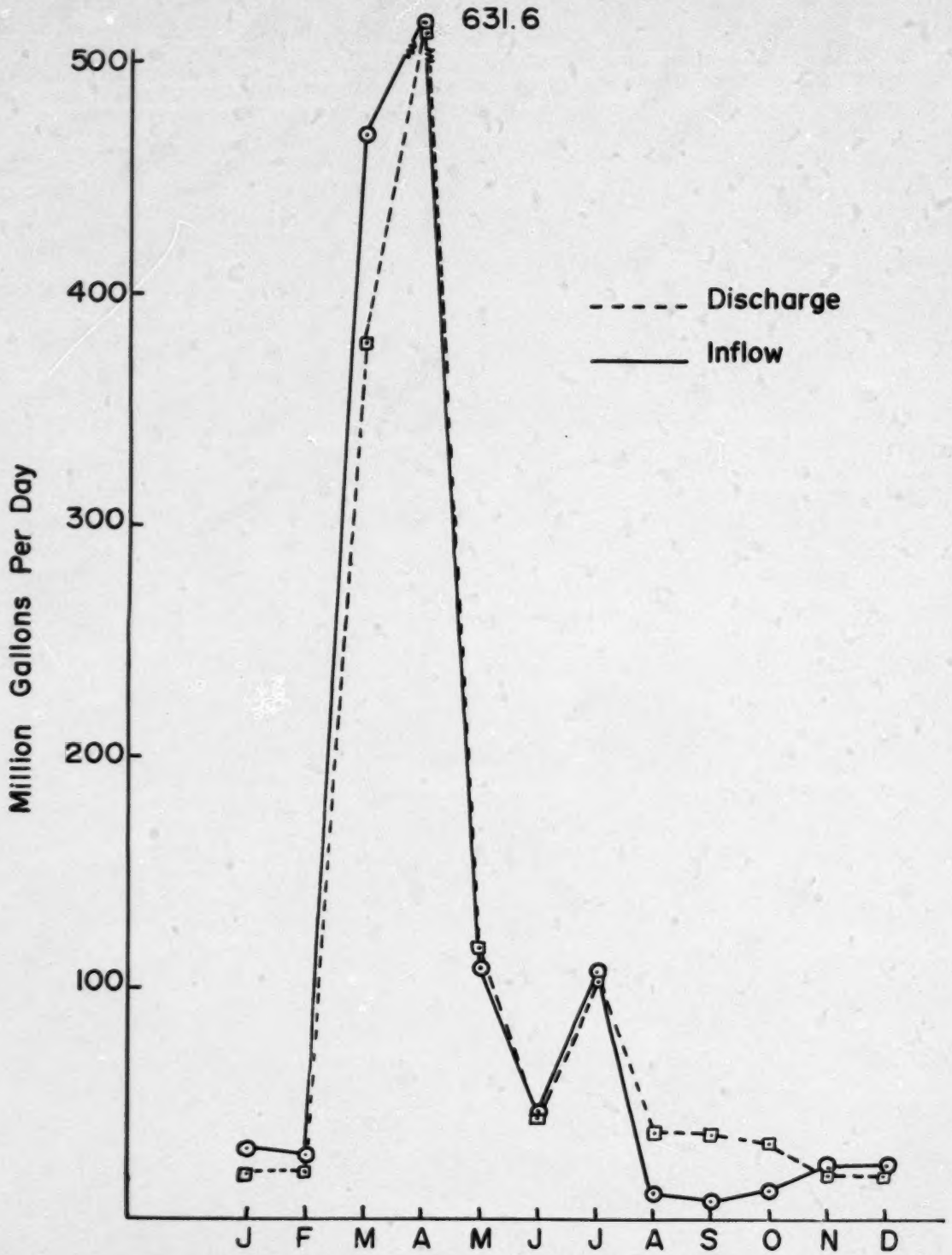

Figure 3. Inflow and Discharge, Geist Reservoir, 1964

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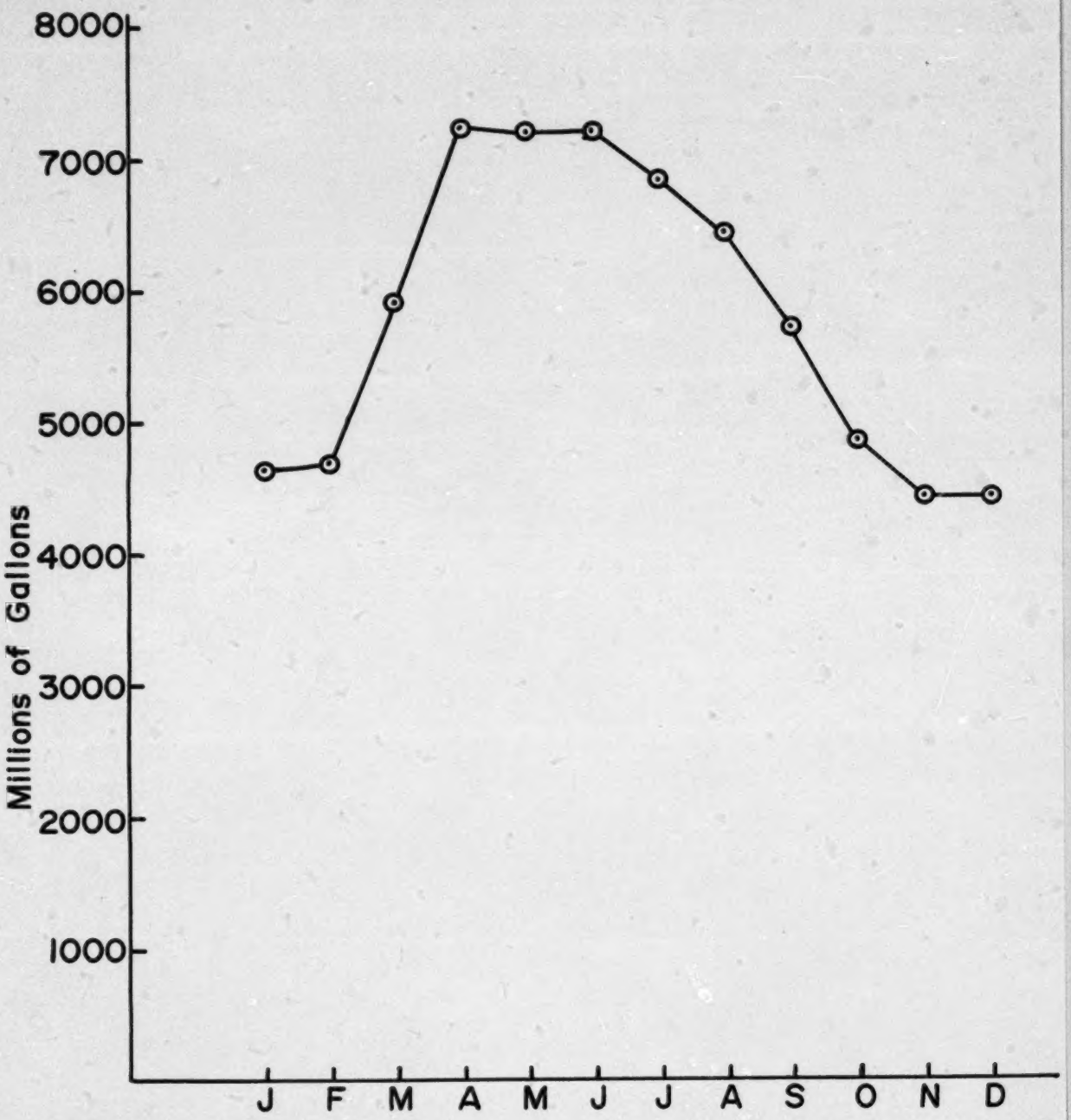

Figure 4. Averaged Monthly Volume, Geist Reservoir, 1963 and 1964

hours spent fishing. The number of bank fishermen was estimated from counts of automobiles present between April 1 to October 31. The average was 58.5 cars per day. It was assumed that the replacement of cars was two times each day, which would be an average of 117 cars per day. An estimate of two persons per car would equal 234 people per day. The total fishing days in 1964 were 214, which resulted in an estimate of 50,000 bank fishermen per year. The marina personnel estimated each bank fisherman to spend four hours fishing each trip. By calculation people spent 200,000 man-hours fishing from the banks of the reservoir.

An average winter has 50 days available for ice fishing. The total time spent ice fishing was estimated at 75,000 man-hours.

During the study period, swimming in Geist Reservoir was prohibited by the Indianapolis Water Company and any future swimming, even if the restriction is removed, would be limited by the available sites for swimming beaches. All beaches would have to be man-made by hauling in sand. Water skiing is likewise prohibited on the reservoir and, if permitted, would be limited to the lower section of the reservoir because of the large number of stumps in the upper basin.

Shoreline residential development has not proceeded on the time schedule that was originally proposed when the study was initiated. Housing in the immediate vicinity of Geist Reservoir is limited currently to a few homes adjacent to the western bank of the reservoir. There is a marina and a sailing club located on the reservoir.

MUNICIPAL AND INDUSTRIAL WASTE SOURCE

Six principal sources of municipal and industrial wastes exist in the drainage basin (Figure 2 and Table 1).

TABLE 1

SOURCES OF POLLUTION

Source	Tributary	P. E. Before Treatment	Treatment	P. E. After Treatment
Fortville	Flat Fork Creek	2,000	Secondary (new plant)	300 E
Ingalls			Septic Tanks	
Indiana Reformatory	Fall Creek	3,300	Secondary (in construction)	2,500 E
Markleville			Septic Tanks	
Pendleton	Fall Creek	3,750	Secondary	335
Middletown	Fall Creek	2,220	Secondary	410

E = Estimated

WATER QUALITY OF GEIST RESERVOIR

This section provides a summary of physical, chemical, and biological data that were obtained during 1963 and 1964. Samples were analyzed according to procedures in Standard Methods for the Examination of Water and Wastewater (Eleventh Ed.).

Dissolved Oxygen and Temperature

Vertical water temperatures and dissolved oxygen concentrations were determined at selected points throughout the reservoir during the spring and summer of 1964. Between the dam and the lower causeway stations, temporary thermal stratification was exhibited from June through August during periods of calm weather (Figure 5). The euphotic zone (that portion of the reservoir in which there is sufficient light for photosynthesis) was approximately 10 ft. and contained up to 18 mg/l of dissolved oxygen (D.O.). The layer of water varying from 2 to 10 feet above the bottom contained less than 0.5 mg/l D.O. during June and July 1964. During the routine sampling in 1963 and 1964, D.O. concentration and water temperatures were recorded at a five-foot level at four reservoir stations (Table 2, Table 3, Figure 5, and Figure 6). These data show that the supersaturated dissolved oxygen concentration in the upper water layer was the result of photosynthesis and the low dissolved oxygen concentrations in the bottom water layer resulted from the respiration of settled organisms and the decomposition of wastes entering the reservoir.

From April to November the water temperature varied from a minimum of 10°C to a maximum of 27°C. The greatest rate of change (10°C per month) occurred during March and April. Maximum water temperatures of 27°C were recorded during late July and early August

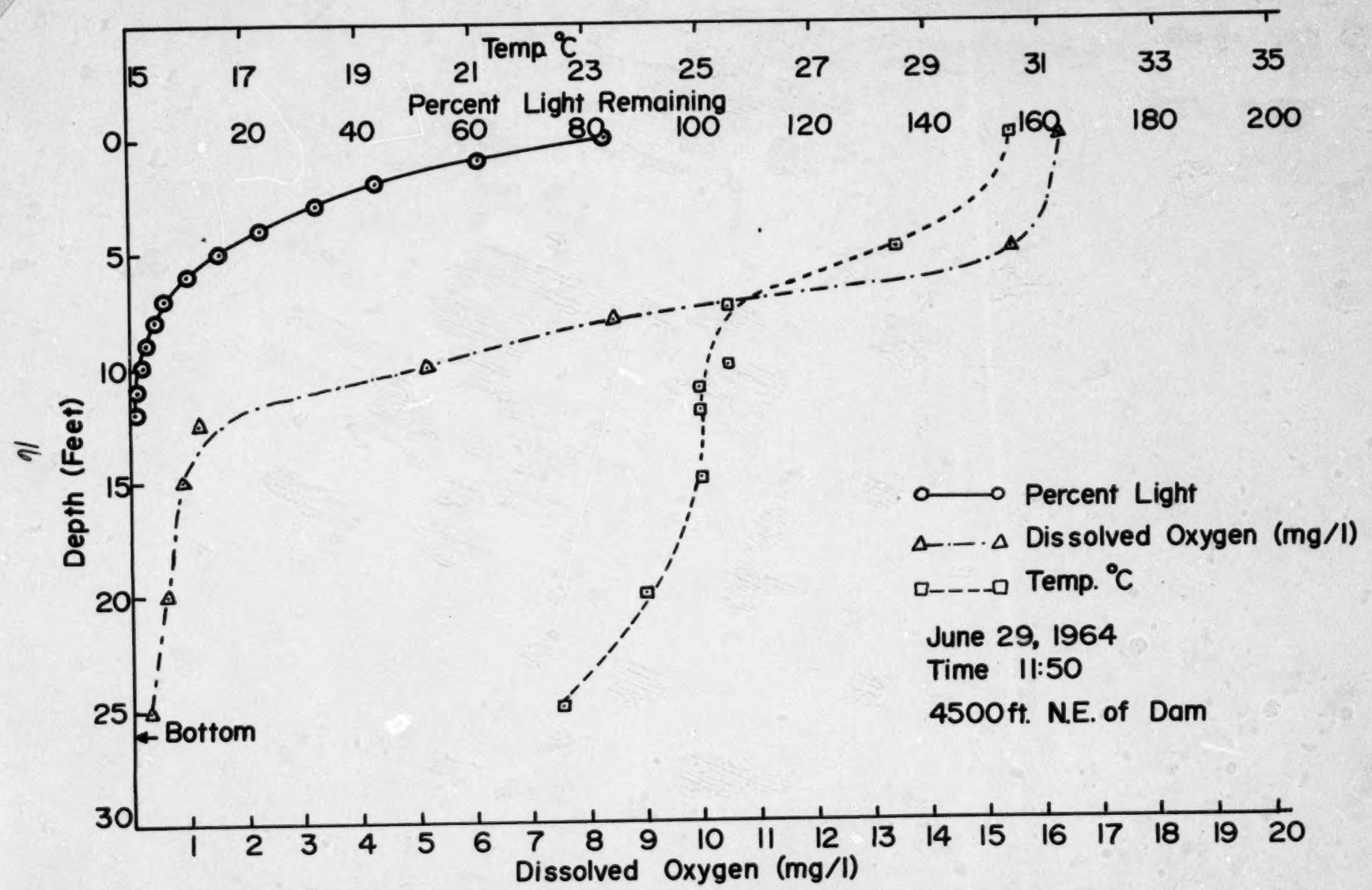
Temp. °C
15 17 19 21 23 25 27 29 31 33 35
Percent Light Remaining
0 20 40 60 80 100 120 140 160 180 200
Depth (Feet)
0 5 10 15 20 25 30
Bottom
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Dissolved Oxygen (mg/l)
Percent Light
Dissolved Oxygen (mg/l)
Temp. °C
June 29, 1964
Time 11:50
4500ft. N.E. of Dam

Figure 5. Vertical Temperature, Dissolved Oxygen, and Percent Light, Geist Reservoir, Indiana.

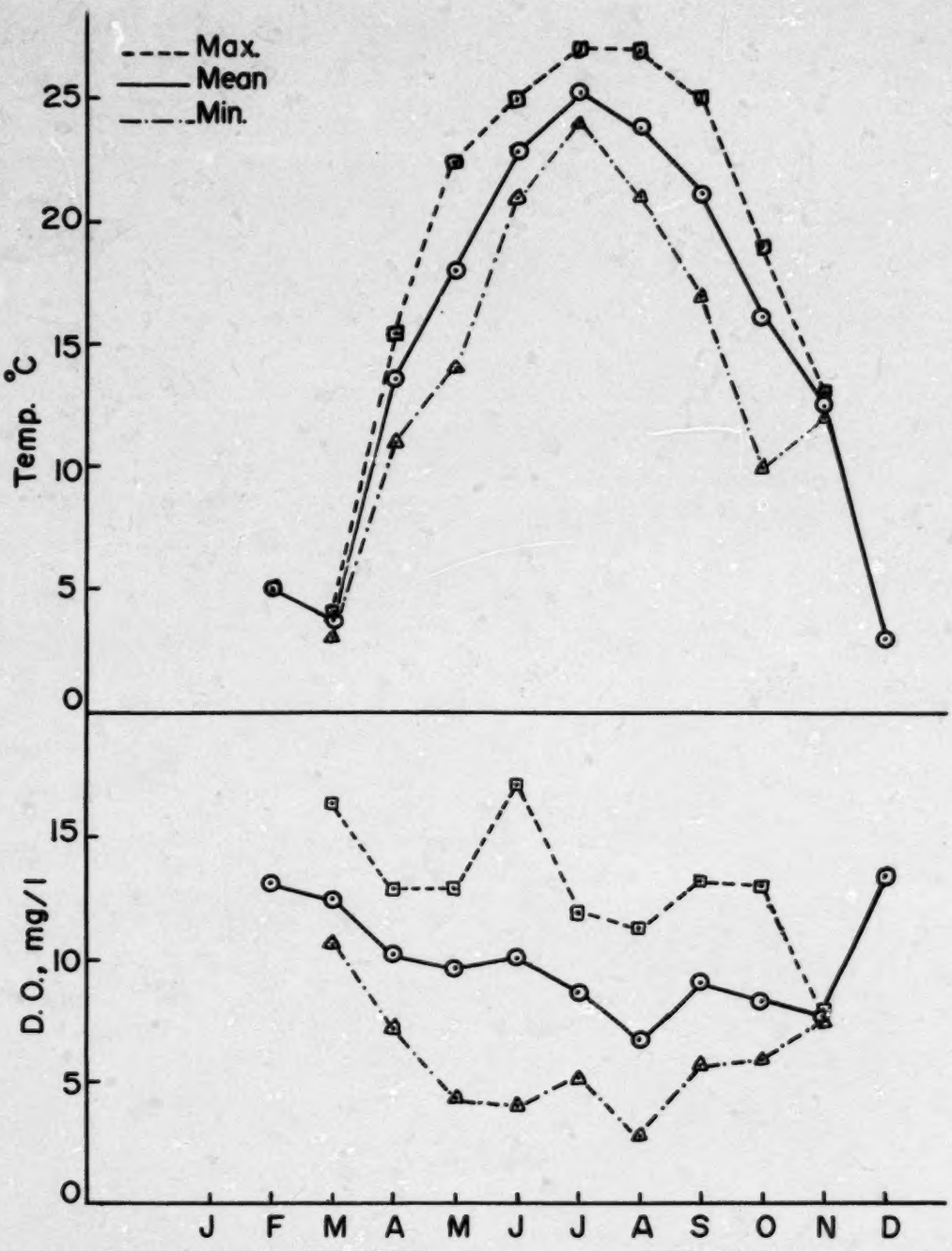

Figure 6. Averaged Monthly Water Temperature and Dissolved Oxygen Concentration, Five Foot Depth, Dam Station, Geist Reservoir 1963 and 1964

(Figure 5). The greatest variation from surface to bottom of the reservoir was 7°C. The average variation was 5°C.

Nutrient Studies

On the premise that the development of the land area surrounding Geist Reservoir for both housing and recreation could increase the amount of algal nutrients entering the reservoir, a nutrient study involving nitrogen and phosphorus determinations was conducted. Nitrogen and phosphorus were studied most intensively because the production of nuisance quantities of algae has been associated with quantities of these two nutrients entering a body of water. In Geist Reservoir, inorganic nitrogen (NH_3-N, NO_3-N) and soluble phosphorus were always present in large quantities even during the maximum algal growing season in June. By calculation, 793,000 lbs. per year of inorganic nitrogen entered Geist Reservoir and 443,000 lbs. flowed out (Table 4); the difference between these two values indicates 44 percent retention. Geist Reservoir contained an average inorganic nitrogen concentration of 1.2 mg/l, based on the mean monthly quantity of inorganic nitrogen divided by the mean reservoir volume. The season of major runoff (March and April) accounted for 633,400 pounds of inorganic nitrogen entering, and 375,040 pounds or 59 percent of the total annual inorganic nitrogen inflow leaving Geist Reservoir.

The total amount of inorganic nitrogen present in Geist Reservoir during March was 128,000 lbs. (Figure 7). This quantity

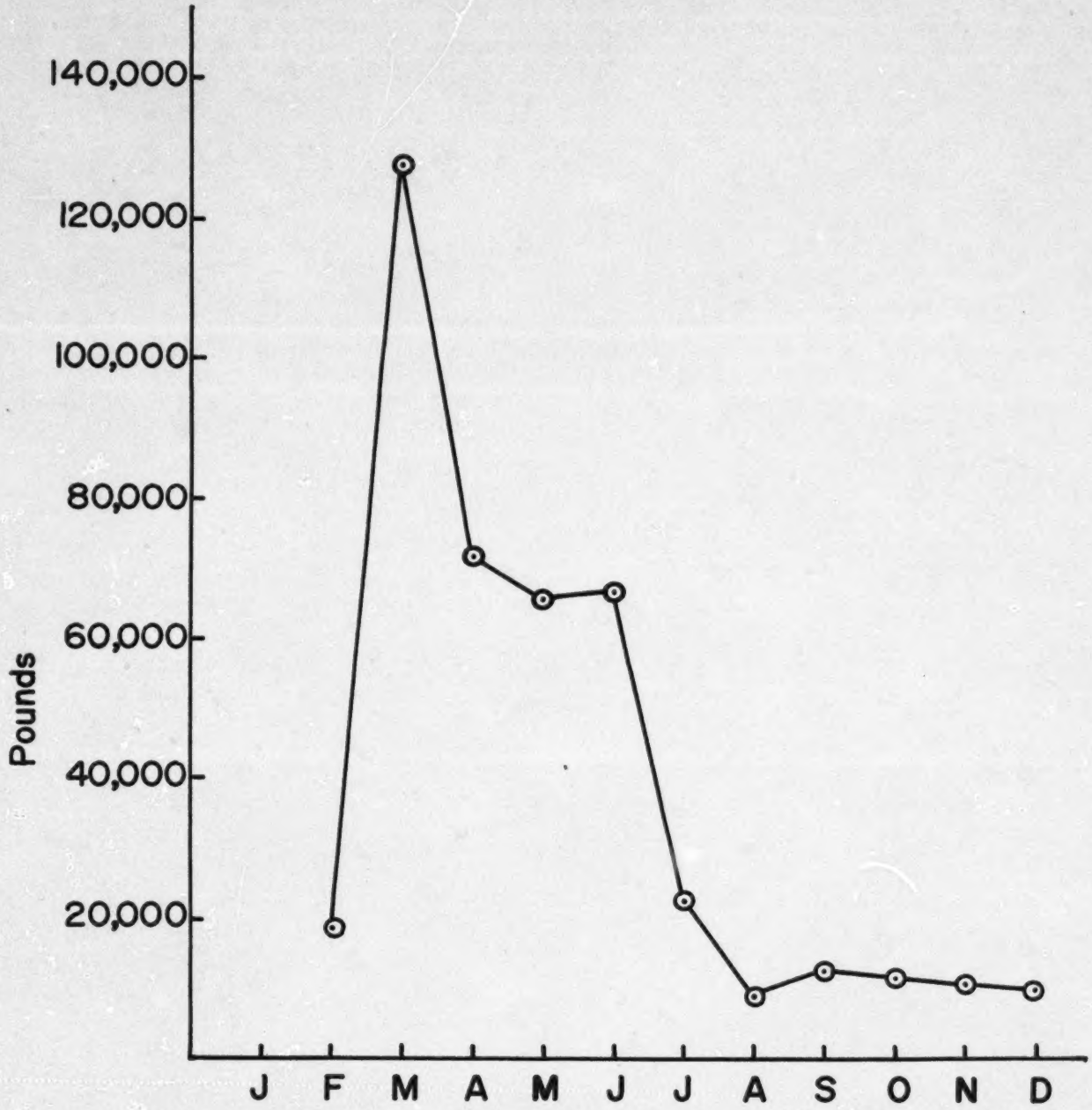

Figure 7. Averaged Monthly Pounds of Total Inorganic Nitrogen in Geist Reservoir, 1963 and 1964

steadily decreased through July. From August through December Geist Reservoir contained, at all times, at least 10,000 lbs. of inorganic nitrogen that was available for algal production. By calculation of the influent concentrations of inorganic nitrogen, the drainage area was supplying 3,690 lbs. of inorganic nitrogen per square mile of drainage per year. This loading is equivalent to 440 lbs. per surface acre in the reservoir per year.

On an annual basis, 51,000 pounds of total phosphorus, of which 38,300 was soluble, entered Geist Reservoir (Table 5). The outflow was 38,400 pounds of which 23,600 was soluble. This provides a 25 percent retention of total phosphorus and a 38 percent retention of soluble phosphorus. The average annual concentration of soluble phosphorus (P) in Geist Reservoir was 0.06 mg/l (Table 6). By calculation, 61 percent of the annual soluble phosphorus entered Geist Reservoir during March and April, and during that same period 90 percent of the soluble phosphorus was discharged. During the period of maximum algal production (June) the inorganic nitrogen concentration was 0.39 mg/l and the soluble phosphorus concentration was 0.014 mg/l indicating that these nutrients were not completely utilized.

By calculating the reservoir volume and the concentration of soluble phosphorus the pounds available for algal production can be estimated. During the month of April, an average quantity of 6,800 pounds of soluble phosphorus was available (Figure 8). This quantity

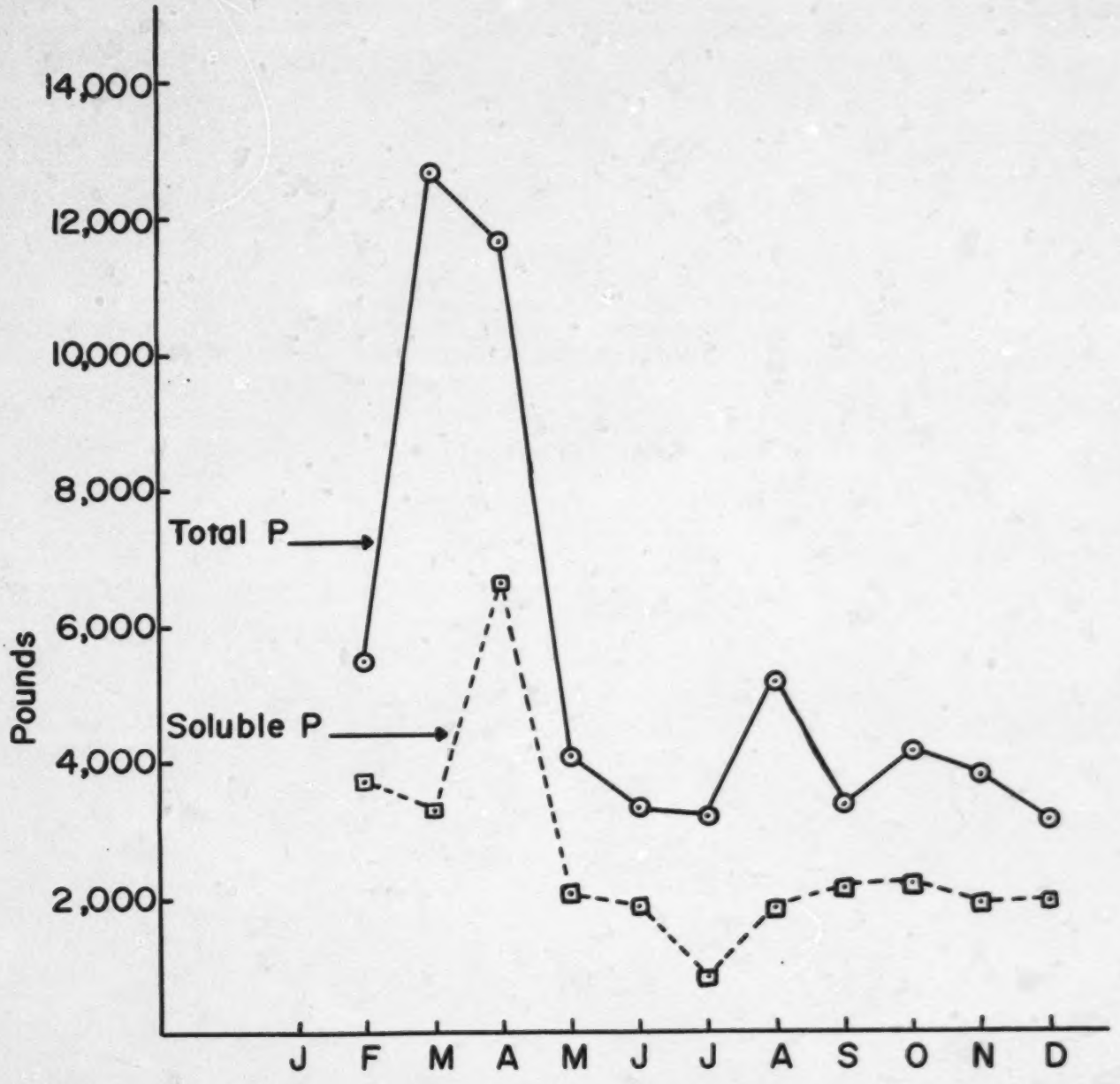

Figure 8. Averaged Monthly Pounds of Total and Soluble Phosphorus in Geist Reservoir, 1963 and 1964

was reduced to 2,000 pounds during May and June. The minimum level of soluble phosphorus occurred during July of both 1963 and 1964 when 900 pounds of soluble phosphorus was available for algal production in the reservoir. During August to December Geist Reservoir contained approximately 2,000 pounds of soluble phosphorus. During 1963 and 1964, the percent soluble phosphorus of the total phosphorus ranged from a minimum of 25 percent to a maximum of 71 percent, and averaged 45 percent.

The drainage area supplied an average of 240 pounds of total phosphorus per square mile. This amount includes that which is drained from the soil, as well as that which is discharged by sparsely populated rural and urban communities. Others have found similar quantities draining from rich farmlands. For example, 225 pounds of phosphorus (P) per square mile per year has been reported in drainage from the Kaskaskia River in Illinois,[1] and agricultural drainage near Madison, Wisconsin, has been found to contribute 255 pounds of phosphorus per square mile per year.[2] This amount of phosphorus (240

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1. Engelbrecht, R. S. and J. J. Morgan. 1961. Land Drainage as a Source of Phosphorus in Illinois Surface Waters. Algae and Metropolitan Wastes, U. S. Public Health Service, SEC TR W61-3, pp. 74-79.

2. Sawyer, C. N. 1947. Fertilization of Lakes by Agricultural and Urban Drainage. Journ. New England Water Works Assn., Vol. 61, No. 2, pp. 109-127.

pounds), from the drainage is equivalent to a reservoir loading of 28 pounds per surface acre. By calculation, the average concentration of total phosphorus in the reservoir was 0.11 mg/l.

It is estimated that the contribution of phosphorus and inorganic nitrogen by fishermen would not exceed 0.2 percent of the total inflow of phosphorus and 0.05 percent of the total inorganic nitrogen entering Geist Reservoir. The magnitude of recreation that would be required to add sufficient algal nutrients to Geist Reservoir to be a significant contribution is far in excess of the recreational potential. The drainage area of 215 square miles can already supply inorganic nitrogen and soluble phosphorus in excess of that presently being used by the phytoplankton population.

Turbidity

During the spring runoff period, March through May, the average turbidity was 155 units for the influent and upper causeway stations (Table 7). A large portion of the particulate matter settled out so that the mean turbidity was 30 units at the dam station. Maximum turbidity readings during this period at inlet and upper causeway stations were 950 units. The maximum during that period at the dam station was 75 units. Figure 9 shows the decrease of turbidity both with time and distance from the influent and with season of the year. Minimum turbidities of five units occurred several times at the dam station.

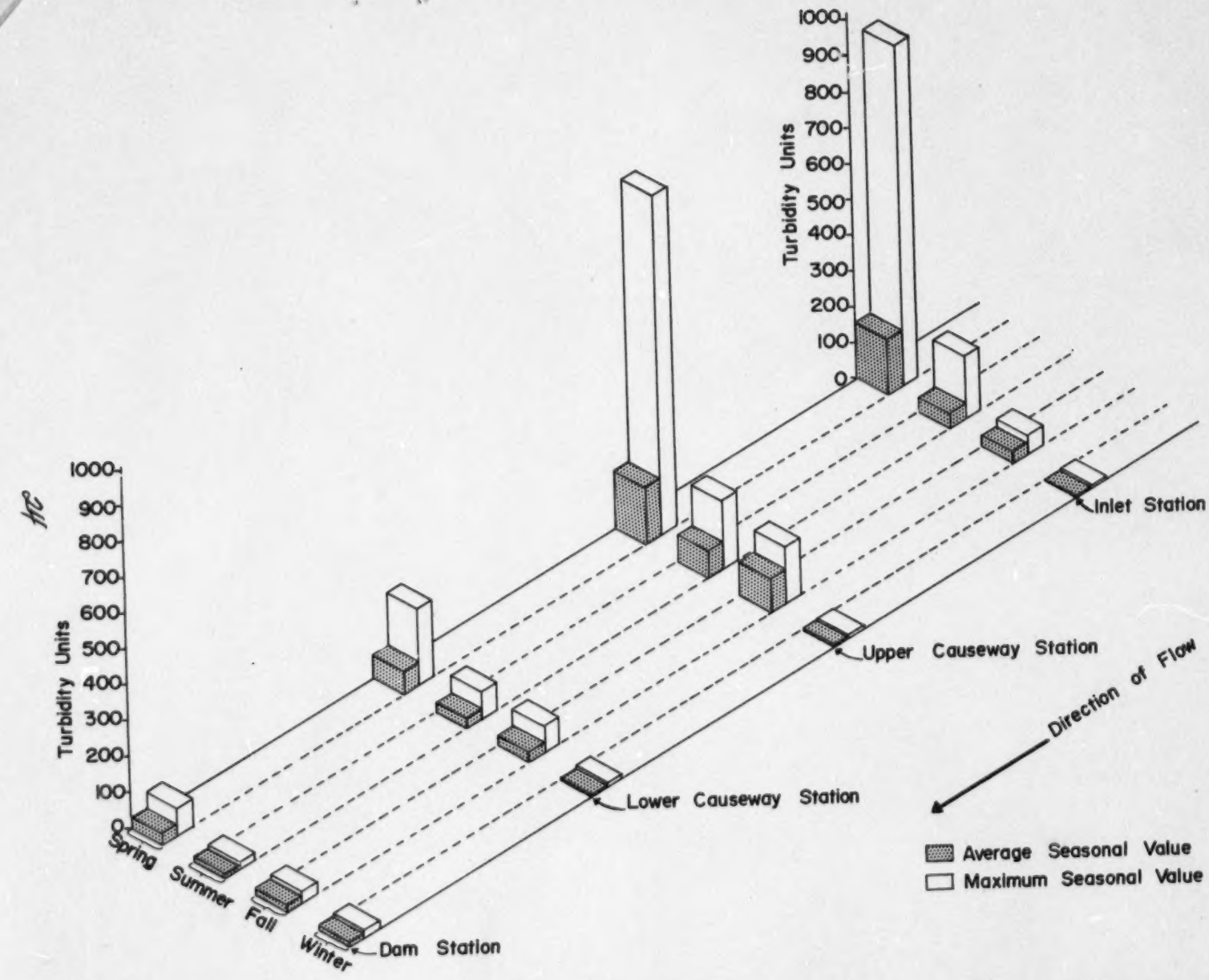

Figure 9. Seasonal Turbidity Values, Geist Reservoir 1963-64

Phytoplankton

A study of the phytoplankton was conducted because this facet of the environment might best reflect changes in water quality resulting from the development of the adjoining lands and increased recreation. Figure 10 exhibits the annual average standing crop for 1963 and 1964, by month.

During the winter period (December-February) there was a standing crop of 383,000 pounds of phytoplankton (wet weight) Figure 10, based on cell and lake volumes. This is equivalent to 213 pounds per acre. The average concentration (25 ppm) of phytoplankton at the lower causeway station was higher than any of the other three stations (Figure 11). Volumetrically, the predominant alga during this period was Diatoma sp.

By calculation, during the spring period (March-May) the average standing crop was 824,000 lbs. (wet weight) or 458 pounds per acre. Monthly average concentrations of 14 ppm were observed at both the lower causeway and dam stations. Volumetrically, the predominant alga during the spring period was Cyclotella sp. Volumetric measurements of the phytoplankton mass and reservoir volume indicate that during the summer period, June-August, the reservoir contained 1,721,000 pounds of algae (wet weight) or an average of 53 ppm. This is equivalent to 960 lbs. per acre. The greatest concentration of algae in a given sample was 428 ppm of which 417 were pigmented

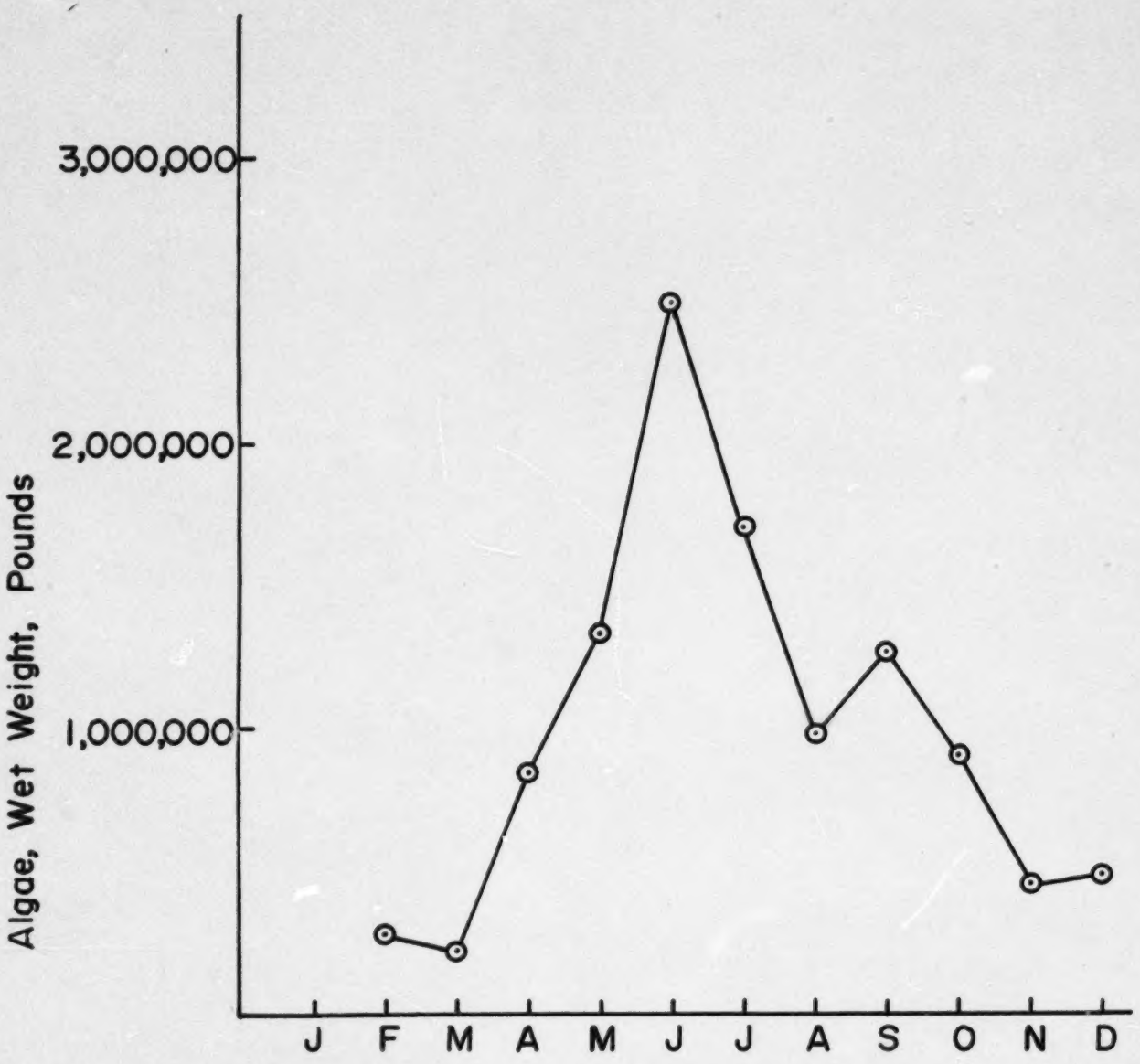

Figure 10. Averaged Monthly Standing Crop of Algae, Geist Reservoir, 1963 and 1964

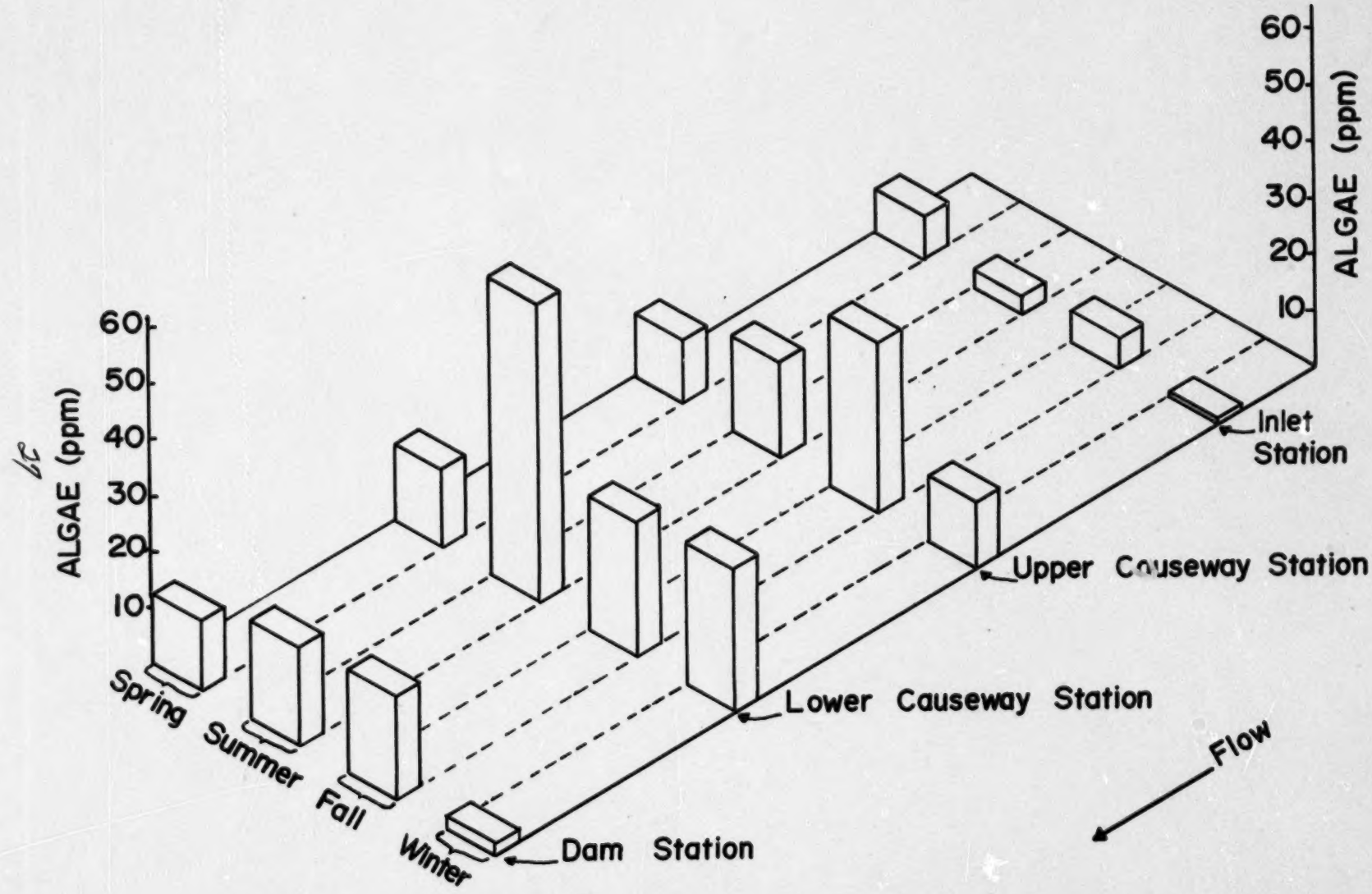

Figure 11. Concentration of Algae (ppm.), Geist Reservoir 1963-64

flagellates (Table 8). This sample was from the lower causeway station on June 17, 1963. By calculation Geist Reservoir contained a maximum of 2.5 million pounds of algae (wet weight). During the summer period Euglena aqueous and Cyclotella sp. predominated volumetrically.

Based on volumetric measurements, during the fall period, September-November, the average standing crop of phytoplankton declined to the level observed during the spring, 871,000 lbs. (wet weight) or 484 pounds per acre. The average volumetric concentration during this period was 20 ppm; the reservoir volume was reduced during this period. The predominant algae during this period were Euglena aqueous and Melosira sp.

Bacteria

The membrane filter technique was used for the coliform, fecal coliform, and the enterococcus tests. As shown in Figure 12 the most significant part of the bacterial data was the reduction of the bacterial population through the reservoir. During the high runoff spring period when the time of passage was reduced to approximately two days, the reduction of bacteria was not as significant as during the summer period when the time of passage was extended to 700 days. The percent reduction based on the average of the three different tests employed was: total coliform 99.1 percent; fecal coliform 98.2 percent; and enterococcus, 91.7 percent (Tables 9 and 10).

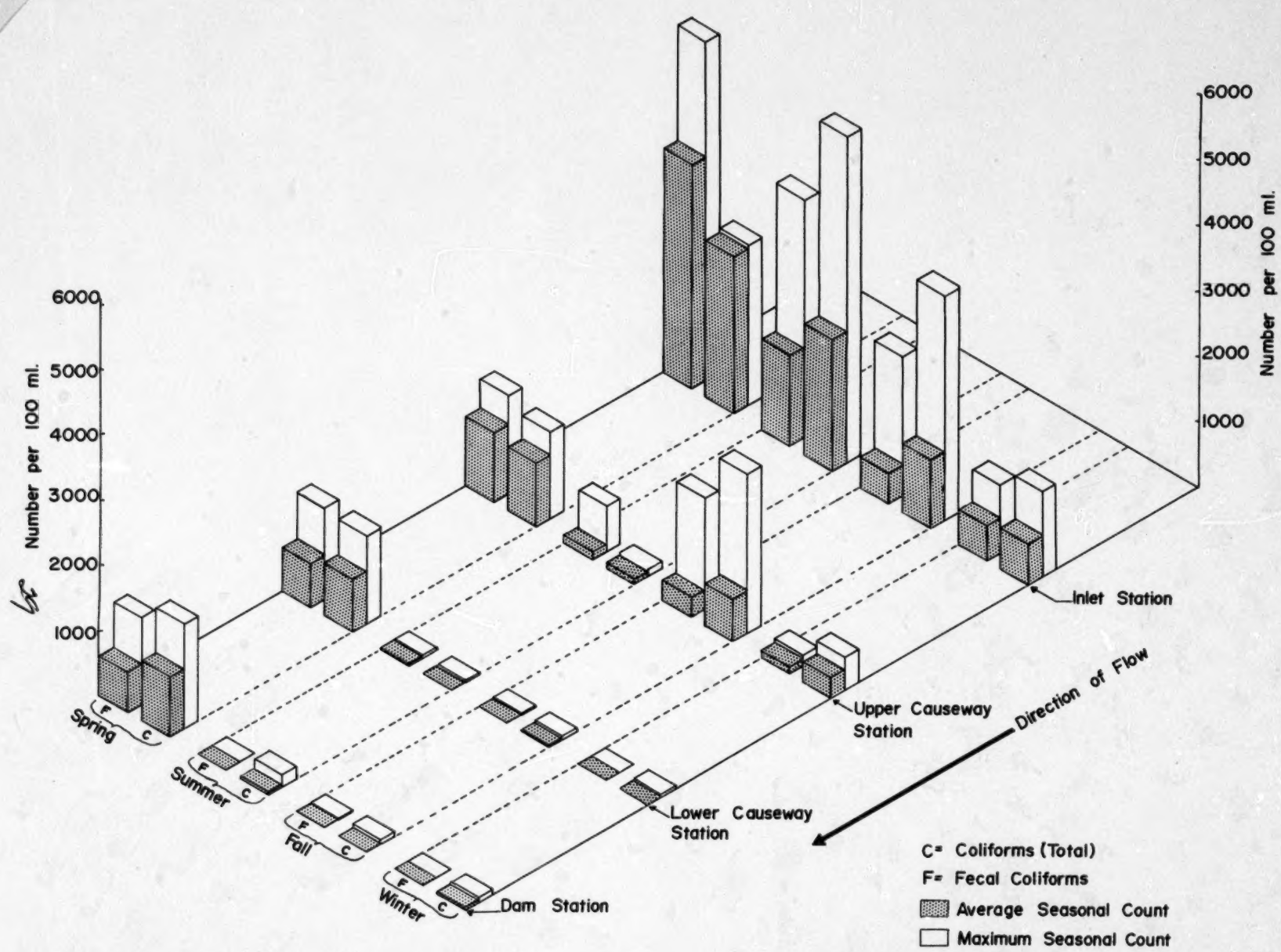

Figure 12. Total and Fecal Coliform Count, Geist Reservoir 1964

Bottom Organisms

The benthonic population in the middle basin reached a maximum of 1,180 organisms per square foot (Table 11). Sludgeworms predominated in the benthos and reached a population of 752 individuals per square foot. The benthonic population in the lower basin contained a maximum of 2,600 organisms per square foot and, like that in the middle basin, was predominantly sludgeworms. Sludgeworms and phantom midge populations were significantly higher in the lower basin than in the upper basin. Higher phantom midge populations in the lower basin were attributed to the deeper water which reached a maximum depth of 30 feet.

The composition and magnitude of the benthonic population observed in Geist Reservoir are usually associated with a body of water that is moderately productive. Physical factors such as temperature, fluctuating water levels, depth and bottom types influenced the bottom organism population to such an extent that any moderate increase in recreation or land development would be insignificant in effecting changes.

Other Chemical Data

Table 12 presents the gross mineral analyses conducted on the influent and outlet stations of Geist Reservoir for 1964. These data indicate there are sufficient quantities present in Geist Reservoir so that these trace elements are not limiting the development of the algal population.

Gross mineral analyses indicate an acceptable water quality for a public water supply at the dam station. Only iron, in 1 of 4 analyses, for the various chemical constituents covered, exceeded the concentration of 0.3 mg/l recommended as a maximum level in the Public Health Service Drinking Water Standards, 1962.

TABLE 2

DISSOLVED OXYGEN IN mg/l

GEIST RESERVOIR - INDIANA

1963 and 1964

Sample Depth - 5 feet Below Surface

	Inlet Station			Upper Causeway Station			Lower Causeway Station			Dam Station		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	13.6	-	-	14.1	-	-	19.4	-	-	13.1
Mar.	11.8	9.0	10.7	11.6	9.1	10.6	14.4	11.0	11.7	16.4	10.7	12.5
April	9.9	7.0	8.3	11.5	7.7	9.6	13.0	7.2	10.8	12.9	7.2	10.1
May	9.9	7.0	7.7	14.7	6.7	10.6	16.1	6.4	11.9	12.9	4.3	9.6
June	7.7	5.4	6.3	17.6	4.2	10.3	17.2	6.3	11.0	17.1	4.0	10.0
July	12.7	5.0	6.4	12.9	5.1	9.0	10.4	5.5	8.0	11.9	5.2	8.7
Aug.	9.6	5.1	6.6	11.6	3.7	8.0	10.6	3.5	7.4	11.2	2.8	6.8
Sept.	8.6	6.6	7.6	9.5	4.4	7.1	11.0	6.6	8.0	13.1	5.7	9.0
Oct.	11.4	7.3	8.6	10.8	6.3	8.0	14.0	7.3	9.2	13.0	5.9	8.3
Nov.	11.0	8.8	9.9	9.6	8.5	9.1	10.1	9.7	9.9	7.9	7.5	7.7
Dec.	-	-	14.6	-	-	14.3	-	-	20.6	-	-	13.5

Feb. and Dec. had only one value

Feb., Mar., Nov., and Dec. recorded in 1964 only

TABLE 3

WATER TEMPERATURE IN °C.

GEIST RESERVOIR - INDIANA

1963 and 1964

Sample Depth - 5 feet Below Surface

	Inlet Station			Upper Causeway Station			Lower Causeway Station			Dam Station		
Month	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	1.0	-	-	0.5	-	-	3.5	-	-	5.0
Mar.	8.5	2.0	4.7	8.0	2.0	4.3	6.0	4.0	4.3	4.0	3.0	3.8
April	18.0	11.0	14.0	17.5	11.0	14.3	16.0	13.0	14.5	15.5	11.0	13.6
May	21.0	13.0	17.5	22.0	13.0	18.7	23.0	14.0	18.7	22.5	14.0	18.0
June	24.0	16.0	20.9	29.0	18.0	23.0	26.0	20.0	23.2	25.0	21.0	22.9
July	24.0	21.0	22.5	26.0	22.0	24.4	26.5	24.0	25.1	27.0	24.0	25.2
Aug.	26.5	18.5	21.5	28.0	19.5	23.3	28.0	21.0	23.7	27.0	21.0	23.8
Sept.	22.0	13.5	18.6	24.0	13.0	19.7	24.0	15.0	20.8	25.0	17.0	21.2
Oct.	17.0	7.5	13.7	16.0	6.5	13.6	18.0	9.0	15.5	19.0	10.0	16.2
Nov.	13.0	10.5	11.8	11.5	9.5	10.5	13.5	11.0	12.2	13.0	12.0	12.5
Dec.	-	-	1.5	-	-	1.5	-	-	2.5	-	-	3.0

Feb. and Dec. had one reading only which was recorded as mean.

Feb., Mar., Nov., and Dec. had no readings from 1963.

TABLE 4

INORGANIC NITROGEN IN mg/l as N

GEIST RESERVOIR - INDIANA

1963 and 1964

Sample Depth - 5 feet Below Surface

	Inlet Station			Upper Causeway Station			Lower Causeway Station			Dam Station		
Month	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Jan	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	1.45	1.45	1.45	0.86	0.86	0.86	0.83	0.83	0.83	0.29	0.29	0.29
Mar.	6.01	3.02	4.32	7.03	2.97	4.56	5.66	3.44	4.32	3.03	0.25	1.67
April	2.16	0.84	1.22	2.36	0.15	1.10	2.82	0.41	1.25	2.04	0.30	1.20
May	2.47	0.71	1.43	2.93	0.40	1.08	2.20	0.30	0.92	1.74	0.63	1.10
June	7.11	0.66	2.02	3.26	0.43	1.02	3.40	0.17	1.00	6.0	0.20	1.27
July	2.77	0.37	1.56	3.90	0.09	1.30	1.21	0.06	0.55	0.61	0.07	0.28
Aug.	0.74	0.17	0.49	0.58	0.06	0.11	0.62	0.06	0.17	0.57	0.07	0.16
Sept.	2.88	0.18	0.70	1.29	0.06	0.52	1.02	0.06	0.35	0.53	0.06	0.19
Oct.	0.80	0.10	0.46	0.83	0.12	0.70	0.51	0.06	0.31	0.30	0.06	0.25
Nov.	0.92	0.39	0.66	0.44	0.29	0.37	0.25	0.10	0.17	0.27	0.15	0.21
Dec.	1.18	1.18	1.18	0.83	0.83	0.83	0.41	0.41	0.41	0.18	0.18	0.18

Inorganic Nitrogen Data - 1964

Pounds entering	793,250
Average concentration entering	2.2 mg/l
Average pounds present	14,537
Average concentration present	1.2 mg/l
Pounds retained	350,120
Percent retained	44.1
Outflow	443,130
Average concentration outflow	1.2 mg/l
Pounds/acre (loading)	440
Pounds/acre foot (loading)	37
Pounds/sq. mile drainage/yr	3,689

TABLE 5

TOTAL PHOSPHORUS IN mg/l as P

GEIST RESERVOIR - INDIANA

1963 and 1964

Sample Depth - 5 feet Below Surface

	Inlet Station			Upper Causeway Station			Lower Causeway Station			Dam Station		
Month	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	.369	.369	.369	.369	.369	.369	.176	.176	.176	.113	.113	.113
Mar.	.234	.003	.130	.202	.068	.124	.258	.002	.109	.157	.002	.098
April	.61	.035	.252	.41	.029	.28	.500	.060	.22	.42	.051	.18
May	.40	.113	.190	.46	.048	.14	.38	.010	.08	.28	.011	.060
June	.317	.071	.195	.258	.061	.15	.126	.038	.081	.125	.010	.040
July	.450	.029	.214	.205	.048	.123	.138	.029	.065	.078	.010	.040
Aug.	.388	.126	.306	.308	.163	.222	.268	.107	.14	.114	.029	.080
Sept.	.496	.330	.371	.396	.198	.319	.252	.045	.123	.100	.038	.060
Oct.	.638	.339	.428	.560	.212	.406	.218	.084	.124	.138	.062	.077
Nov.	.443	.258	.355	.579	.265	.422	.112	.097	.104	.091	.084	.087
Dec.	.339	.339	.339	.285	.285	.285	.097	.097	.097	.068	.068	.068

Total Phosphorus - 1964

Pounds entering	51,000
Average concentration entering	0.14 mg/l
Average pounds present	5,236
Average concentration present	0.11 mg/l
Pounds retained	12,576
Percent retained	25
Outflow	38,424
Average concentration outflow	0.107 mg/l
Pounds/acre (loading)	28
Pounds/acre foot (loading)	2.4
Pounds/sq. mile drainage/yr	240

TABLE 6

SOLUBLE PHOSPHORUS IN mg/l as P

GEIST RESERVOIR - INDIANA

1963 and 1964

Sample Depth - 5 feet Below Surface

	Inlet Station			Upper Causeway Station			Lower Causeway Station			Dam Station		
Month	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	.339	.339	.339	.339	.339	.339	.176	.176	.176	.045	.045	.045
Mar.	.157	.003	.078	.172	.025	.074	.211	.000	.103	.082	.001	.040
April	.360	.010	.203	.410	.010	.080	.400	.001	.150	.212	.001	.090
May	.340	.062	.134	.300	.016	.066	.200	.001	.040	.120	.001	.030
June	.218	.046	.159	.192	.035	.100	.084	.010	.031	.035	.001	.028
July	.320	.029	.160	.163	.048	.051	.119	.003	.025	.045	.001	.006
Aug.	.360	.045	.254	.252	.073	.172	.176	.026	.050	.045	.006	.020
Sept.	.459	.268	.345	.320	.125	.275	.113	.026	.064	.051	.006	.024
Oct.	.548	.280	.371	.480	.163	.326	.205	.029	.056	.138	.019	.040
Nov.	.278	.212	.245	.405	.225	.286	.100	.062	.060	.035	.029	.032
Dec.	.258	.258	.258	.218	.218	.218	.019	.019	.019	.019	.019	.019

Soluble Phosphorus - 1964

Pounds entering	38,270
Average concentration entering	0.101 mg/l
Average pounds present	2,449
Average concentration present	0.06 mg/l
Pounds retained	14,700
Percent retained	38
Outflow	23,570
Average concentration outflow	0.064 mg/l
Pounds/acre (loading)	21
Pounds/acre foot (loading)	1.8
Pounds/sq. mile drainage/yr	178

TABLE 7

TURBIDITY VALUES IN TURBIDITY UNITS

GEIST RESERVOIR - INDIANA

1963 and 1964

Sample Depth - 5 feet Below Surface

	Inlet Station			Upper Causeway Station			Lower Causeway Station			Dam Station		
Month	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	5	-	-	5	-	-	5	-	-	15
Mar.	800	10	296	800	25	261	220	30	105	75	15	40
April	950	10	155	950	35	182	110	30	59	55	20	34
May	35	5	16	90	15	35	45	13	30	30	5	17
June	180	15	52	95	30	67	45	15	27	15	10	12
July	120	25	55	85	40	75	55	13	38	15	5	12
Aug.	50	10	28	190	45	96	75	20	42	20	5	15
Sept.	50	10	29	160	80	115	60	15	40	35	5	19
Oct.	40	5	23	110	25	77	75	15	42	35	10	26
Nov.	10	5	7.5	110	80	95	25	25	25	20	20	20
Dec.	-	-	5	-	-	5	-	-	10	-	-	10

TABLE 8

PHYTOPLANKTON IN ppm (Wet Wgt.)

GEIST RESERVOIR - INDIANA

1963 and 1964

Sample Depth - 5 feet Below Surface

	Inlet Station			Upper Causeway Station			Lower Causeway Station			Dam Station		
Month	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	0.1	1.21	1.21	1.21	19.2	19.2	19.2	11.0	11.0	11.0
March	3.62	0.7	2.7	4.76	1.7	25.3	9.81	8.6	6.2	48.8	2.0	3.1
April	19.8	0.56	6.7	19.9	0.48	7.6	29.9	0.5	9.5	30.3	0.92	14.4
May	12.7	1.4	6.5	37.0	3.0	16.6	44.0	9.8	27.6	51.0	8.0	21.6
June	7.8	1.9	3.3	174.2	3.8	48.8	427.9	2.4	89.7	28.8	1.8	17.2
July	5.1	1.16	2.4	48.6	15.1	22.2	103.8	6.0	45.6	45.9	6.7	23.1
Aug.	8.9	1.8	4.9	60.9	5.4	20.8	53.7	5.7	25.9	30.9	4.4	14.3
Sept.	29.4	3.5	13.2	93.9	9.4	24.0	62.7	15.4	27.2	89.3	6.8	26.4
Oct.	4.5	1.2	3.5	24.3	3.2	10.4	30.7	11.0	22.9	53.1	9.3	22.9
Nov.	9.79	5.12	7.5	8.1	6.5	7.3	23.0	20.1	22.0	23.6	12.2	7.3
Dec.	-	-	2.0	-	-	12.1	-	-	31.0	-	-	4.4

TABLE 9

BACTERIA IN NUMBER PER 100 ml

GEIST RESERVOIR - INDIANA

1963

Sample Depth - 5 feet Below Surface

Month	Inlet Station						Upper Causeway Station					
	Coliform		Fecal Coliform		Enterococcus		Coliform		Fecal Coliform		Enterococcus	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	-	-	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-	-	-	-	-
April	6,800	4,520	4,500	2,370	-	-	6,450	4,240	4,500	2,155	-	-
May	10,100	7,491	3,600	1,920	-	-	5,300	2,714	1,140	270	-	-
June	20,200	12,550	12,250	2,320	180	111	2,840	547	106	22	48	18
July	12,400	5,305	2,000	594	2,000	293	150	81	124	30	60	26
Aug.	10,434	27,000	480	314	96	58	155	74	20	9	35	15
Sept.	9,200	4,187	370	235	56	30	110	55	15	6	16	8
Oct.	5,000	1,418	300	180	80	49	1,180	342	60	18	15	7
Nov.	-	-	-	-	-	-	-	-	-	-	-	-
Dec.	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 9 (continued)

Month	Lower Causeway Station						Dam Station					
	Coliforms		Fecal Coliform		Enterococcus		Coliforms		Fecal Coliform		Enterococcus	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	-	-	-	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-	-	-	-	-
April	7,800	2,441	6,500	1,760	-	-	240	165	230	79	-	-
May	765	306	310	84	-	-	106	34	30	8	-	-
June	220	27	6	3	228	104	68	9	10	3	328	130
July	200	90	100	25	144	47	32	14	24	6	200	62
Aug.	40	21	10	6	40	10	270	44	10	5	55	12
Sept.	20	12	10	5	5	5	40	19	5	5	5	5
Oct.	172	34	5	5	5	5	136	32	12	5	4	4
Nov.	-	-	-	-	-	-	-	-	-	-	-	-
Dec.	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 10

BACTERIA IN NUMBER PER 100 ml

GEIST RESERVOIR - INDIANA

1964

Sample Depth - 5 feet Below Surface

Month	Inlet Station						Upper Causeway Station					
	Coliform		Fecal Coliform		Enterococcus		Coliform		Fecal Coliform		Enterococcus	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	20	-	20	-	-	-	4	-	4	-	-
March	-	-	-	-	-	-	-	-	-	-	-	-
April	-	2,380	-	1,590	-	-	-	640	-	1,500	-	-
May	-	2,400	-	5,200	-	-	-	1,300	-	680	-	-
June	5,000	3,155	3,900	1,771	2,550	600	84	52	72	33	150	57
July	3,800	2,150	3,750	1,960	267	164	140	76	740	372	28	16
Aug.	1,000	826	460	299	80	47	116	77	36	16	28	16
Sept.	1,500	795	600	281	-	-	200	122	64	30	-	-
Oct.	380	350	68	56	-	-	620	364	52	34	-	-
Nov.	3,400	1,940	2,120	1,076	-	-	2,440	1,520	1,740	874	-	-
Dec.	-	1,270	-	1,080	-	-	-	520	-	204	-	-

TABLE 10 (continued)

Month	Lower Causeway Station						Dam Station					
	Coliform		Fecal Coliform		Enterococcus		Coliform		Fecal Coliform		Enterococcus	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Jan.	-	-	-	-	-	-	-	-	-	-	-	-
Feb.	-	12	-	4	-	-	-	24	-	4	-	-
March	-	-	-	-	-	-	-	1,660	-	1,320	-	-
April	-	1,340	-	1,380	-	-	-	130	-	10	-	-
May	-	250	-	20	-	-	-	71	-	4	-	-
June	16	9	8	5	10	6	200	4	4	4	4	4
July	8	6	4	4	4	4	4	4	4	4	4	4
Aug.	12	7	4	4	4	4	4	4	4	4	4	4
Sept.	20	11	8	6	-	-	32	14	20	8	-	-
Oct.	12	8	4	4	-	-	12	8	8	6	-	-
Nov.	16	10	16	10	-	-	20	14	4	4	-	-
Dec.	-	4	-	4	-	-	-	8	-	4	-	-

TABLE 11

BOTTOM ORGANISMS IN NUMBER PER SQUARE FOOT

GEIST RESERVOIR - INDIANA

1964

	Lower Reservoir			Middle Reservoir		
	Max	Min	Mean	Max	Min	Mean
Phantom Midge	1,464	12	314	1,120	0	155
Bloodworm	196	4	85	52	0	11
Sludgeworm	1,904	0	520	952	8	458
Other	160	0	33	72	0	25
Total	2,612	64	953	1,180	220	650

TABLE 12

GROSS MINERAL ANALYSES IN mg/l

GEIST RESERVOIR - INDIANA

1964

Sample Depth - 5 feet Below Surface

INFLOW

Station	Date	Na	K	Ca	Mg	SiO_2	Total Fe	SO_4	Cu	Cd	Ni	Zn	Total Cr
Inlet	4/29	5.6	1.3	40	37	5.2	0.29	60	0.13	x	x	0.05	0.01
	6/25	8.8	1.5	51	40	7.2	1.48	59	0.02	x	0.01	x	0.02
	8/25	6.0	2.1	75	44	8.2	3.00	56	0.05	x	0.01	x	x
	10/10	14.8	2.7	79	45	5.8	1.58	54	0.02	x	x	x	x

DISCHARGE

Dam	4/29	4.0	1.9	34	24	3.3	0.16	46	0.18	x	x	0.03	x
	6/25	5.0	1.7	32	32	2.2	0.10	48	0.07	x	0.01	0.04	x
	8/25	6.3	2.2	37	33	0.6	0.16	42	0.04	x	x	x	x
	10/10	7.0	1.8	41	34	1.6	0.50	46	x	x	x	x	x

x---None found at a sensitivity of 0.01 mg/l.

RECOMMENDED LIMITS *

Nitrate as NO_3	N	Fe	SO_4	Cu	Cd	Zn	Hexavalent Cr
45	10	0.30	250	1.00	0.01	5.0	0.05

* Public Health Service Drinking Water Standards (1962)